MECHANICALLY DEPLOYABLE EXPANDABLE AND COLLAPSIBLE STRUCTURE AND METHOD FOR DEPLOYING A STRUCTURE

BACKGROUND AND SUMMARY

[0001] The present invention relates to expandable and collapsible structures and, more particularly, to mechanically deployable expandable and collapsible structures.

[0002] My prior U.S. Patent Nos. 6,141,934, 5,651,228, 5,444,946, 5,274,980, 5,230,196, RE33,710, 4,970,841, 4,838,003, 4,800,663, 4,761,929, 4,747,239, 4,689,932, 4,666,102, 4,637,180, 4,579,066, 4,561,618, 4,522,008, 4,512,097, 4,473,986, 4,437,275, 4,334,660, 4,290,244, 4,280,521, 4,026,313, and 3,968,808 are incorporated by reference and show various collapsible structures and components therefor. Many expandable and collapsible structures are designed to be erected by workers at ground level. Typically, the workers erect center portions of the structures first, then work their way outward to erect more peripheral portions of the structure. When the erection of the structures is completed, the center portions may be out of the reach of the workers, such as is likely to be the case in the erection of certain of the structures disclosed in U.S. Patent No. 5,444,946. While experienced workers can often erect these structures in relatively little time, it usually takes a team of workers to erect the structures. Additionally, when the structures are unfolded to a collapsed condition prior to forming the erected structure, the peripheral portions of the structures typically extend outwardly substantially beyond the boundaries of the erected structure because the structures are laid out substantially flat prior to erection into their final shape. This can make it necessary to attach covers to the

structures only after the structures are erected because the structures are designed to cover the structures in the erected condition.

[0003] It is desirable to provide an expandable and collapsible structure that can have a cover that is attached to the structure when the structure is folded or expanded. It is also desirable to provide a structure that does not need a team of workers to erect the structure.

[0004] In accordance with one aspect of the present invention, a mechanically deployable, expandable and collapsible structure is provided. The structure includes at least one scissor assembly comprising a first and a second strut, the first and the second strut each having first and second ends and being pivotably attached to each other such that the scissor assembly is movable between a folded position in which the first end of the first strut and the second end of the second strut are substantially adjacent and an expanded position. The structure also includes a first spacer disposed between the first end of the first strut and the first end of the second strut when the scissor assembly is in the expanded position, and a second spacer disposed between the second end of the first strut and the second end of the second strut when the scissor assembly is in the expanded position. A tension member is connected to the first and second struts. The tension member is arranged such that the scissor assembly is moved from the folded position when there is slack in the tension member to the expanded position when the slack in the tension member is taken up.

[0005] In accordance with another aspect of the present invention, a method of deploying a mechanically deployable structure is provided. According to the method, the structure is unfolded to a collapsed condition. The structure includes at least one scissor

assembly comprising a first and a second strut, the first and the second strut each having first and second ends and being pivotably attached to each other such that the scissor assembly is movable between a folded position in which the first end of the first strut and the second end of the second strut are substantially adjacent and an expanded position. When the structure is in a collapsed condition, slack in a tension member is taken up, the tension member being connected to the first and second struts in such a manner that taking up slack draws the first ends of the first and second struts toward one another.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] The features and advantages of the present invention are well understood by reading the following detailed description in conjunction with the drawings in which like numerals indicate similar elements and in which:

[0007] FIG. 1 is a side view of a structure according to an embodiment of the present invention;

[0008] FIGS. 2A and 2B are side views of scissor assemblies according to an embodiment of the present invention in folded and expanded conditions, respectively;

[0009] FIGS. 3A, 3C, and 3D are side, partially cross-sectional views of spacers according to embodiments of the present invention, and FIG. 3B is a broken, perspective view of a spacer according to an embodiment of the present invention;

[0010] FIGS. 4A, 4B, and 4C are front, top, and side views, respectively, of a structure according to an embodiment of the invention;

[0011] FIGS. 5A, 5B, and 5C are front, top, and side views, respectively, of a structure according to an embodiment of the invention;

[0012] FIGS. 6A, 6B, and 6C are front, top, and side views, respectively, of a structure according to an embodiment of the invention;

[0013] FIGS. 7A, 7B, and 7C are front, top, and side views, respectively, of a structure according to an embodiment of the invention;

[0014] FIGS. 8A-8B show front and side views of a structure and FIGS. 8C and 8D show strut pairs from the front and side of the structure of FIGS. 8A and 8B, respectively, according to an embodiment of the present invention in a folded stage of deployment;

[0015] FIGS. 9A-9B show front and side views of a structure and FIGS. 9C and 9D show strut pairs from the front and side of the structure of FIGS. 9A and 9D respectively, according to an embodiment of the present invention in a collapsed stage of deployment;

[0016] FIGS. 10A-10B show front and side views of a structure and FIGS. 10C and 10D show strut pairs from the front and side of the structure of FIGS. 10A and 10B, respectively, according to an embodiment of the present invention in an expanded stage of deployment; and

[0017] FIGS. 11A-11F show perspective views of phases of erection of a structure according to an embodiment of the present invention.

DETAILED DESCRIPTION

[0018] A mechanically deployable, expandable and collapsible structure 21 according to an embodiment of the present invention is seen in FIG. 1. The structure 21 will ordinarily include a cover C (shown in phantom) disposed on an inner side and/or an outer side of the structure. The structure 21 includes at least one and ordinarily a

plurality of scissor assemblies 23. Each scissor assembly 23 includes a first and a second strut 25 and 27, respectively.

[0019] As seen with reference to the scissor assemblies 23s and 23c in FIGS. 2A and 2B, the first and the second struts 25 and 27 each have first and second ends 25' and 25" and 27' and 27". The second ends 25" and 27" of the first and second struts 25 and 27 of one scissor 23s are pivotably connected to the first ends 27' and 25' of the struts 27 an 25 of the succeeding scissor assembly 23c. A hub 137 structure to which ends of the struts are attached is ordinarily provided.

[0020] The first and second struts 25 and 27 are pivotably attached to each other at a connection point 29 such that the scissor assembly is movable between a folded position (FIG. 2A) in which the first end 25' of the first strut and the second end 27" of the second strut are substantially adjacent and an expanded position (FIG. 2B). When the scissor assemblies 23s and 23c are in the expanded position, a first spacer 31 is disposed between the first end 25' of the first strut 25 and the first end 27' of the second strut 27, and a second spacer 33 is disposed between the second end 25" of the first strut and the second end 27" of the second strut. The spacers 31 and 33 are ordinarily identical and the references here to first and second spacers is merely for the sake of discussion and is not intended to reflect differences between the spacers.

[0021] A tension member 35 is connected to the first and second struts 25 and 27. The tension member 35 is arranged such that the scissor assemblies 23s and 23c are moved from the folded position when there is slack in the tension member to the expanded position when the slack in the tension member is taken up. The tension member 35 is

ordinarily in the form of a cable or similar structure and is adapted to be placed in tension.

[0022] The structure 21 (FIG. 1) ordinarily includes a plurality of scissor assemblies 23s and 23c (FIGS. 2A and 2B) connected end to end such that a second end 27" of a second strut 27 and a second end 25" of a first strut 25 of a first scissor assembly 23s is pivotably connected to a first end 25' of a first strut and a first end 27' of a second strut of a second scissor assembly 23c, respectively. In this embodiment, the second spacer 33 for the first scissor assembly 23 serves as the first spacer 31 for the second scissor assembly, i.e., successive scissor assemblies share spacers.

[0023] The plurality of scissor assemblies 23 seen in FIG. 1 connected end to end defines what shall be referred to here as a bank 37 of scissor assemblies. The structure 21 ordinarily includes at least two, usually more, banks 37 of scissor assemblies 23. As seen in FIGS. 4B and 4C, at least one lateral scissor assembly 39 is provided and includes first and second struts 41 and 43 pivotably connected at ends thereof to ends of the first and second struts 25 and 27 of at least one scissor assembly of each of the banks of scissor assemblies. Ordinarily, the banks 37 of scissor assemblies 23 are substantially identical and a lateral scissor assembly 39 is disposed at each end of each scissor assembly.

[0024] As seen in FIGS. 8D, 9D, and 10D, the first and second struts 41 and 43 of the lateral scissor assemblies 39 are preferably telescoping and include interior telescoping portions 41a and 43a pivotably connected to the hubs 137 and exterior telescoping portions 41b and 43b pivotably connected to each other. If desired, of course, the interior portions may be pivotably connected to each other and the exterior portions may be pivotably connected to the hubs. As seen in FIGS. 8A-11F, the use of the telescoping

struts in the lateral scissor assemblies 39 facilitates deployment of the structure 21 by permitting the structure to be opened to its full length without opening the banks 37 of scissor assemblies.

[0025] As seen in, for example, FIG. 4B, the first and second struts 41 and 43 of each lateral scissor assembly 39 may be pivotably connected to each other at a connection point 45. The first and second struts 41 and 43 may be pivotably connected to each other at centerpoints of the first and second struts. If desired, such as for purposes of forming a structure 21 that is higher in the center than at its ends along an axis of the structure, the first and second struts 41 and 43 may be connected at points offset from the centerpoints of the struts.

[0026] As seen in FIG. 2B, ordinarily, the first and second struts 25 and 27 of at least some scissor assemblies 23s of the plurality of scissor assemblies are pivotably connected to each other at connection points 29 disposed at centerpoints of the first and second struts. With a connection point 29 at the centerpoints of the struts, lines extending through the first ends of the first and second struts and through the second ends of the first and second struts of the scissor assembly 23s are parallel and, in an expanded condition, the scissor assemblies define a substantially rectangular shape. If multiple such scissor assemblies 23s are attached, their centerpoints will extend along a straight line.

[0027] However, the first and second struts 25 and 27 of at least one other scissor assembly 23c of the plurality of scissor assemblies are pivotably connected to each other at points 29 offset from centerpoints of the first and second struts. In this way, lines extending through first ends of the first and second struts and through second ends of the

first and second struts of the scissor assembly 23c are not parallel and the scissor assembly defines a truncated triangle shape. If multiple such scissor assemblies 23c are connected end to end, the centerpoints 29 of the assemblies will lie on a curve

[0028] Ordinarily, the structure 21 will be made up of a combination of straight scissor assemblies 23s and curved scissor assemblies 23c. The curved scissor assemblies 23c may be constructed so that they define truncated triangles of different shape, such as truncated triangles truncated from isosceles triangles with two 75°, 67.5°, 60°, or 45° angles.

[0029] As seen in FIG. 1, the plurality of connected scissor assemblies are preferably arranged in a combination of straight scissor assemblies and curved scissor assemblies to define an arch shape when in the expanded condition. The arch includes a first end scissor assembly 23_1 and a second end scissor assembly 23_2 at opposite ends of the plurality of connected scissor assemblies. The arch will ordinarily be shaped, through a suitable combination of curved and straight scissor assemblies, such that the first ends 25' and 27' of the first and second struts 25 and 27 of the first end scissor assembly 23_1 are substantially coplanar with the second ends 25" and 27" of the first and second struts of the second end scissor assembly 23_2.

[0030] The first and second spacers 31 and 33 ordinarily each include tubular or channel-shaped members. As seen in FIG. 2B, the tension member 35 ordinarily extends through at least part of the tubular or channel-shaped first and second spacers 31 and 33, ordinarily from a first end 31' and 33' of each spacer to a second end 31" and 33" of each spacer or proximate the first and second ends. The spacers 31 and 33 may be formed from a single member or, as seen in FIGS. 2A-3D, from plural members. While the

spacers 31 and 33 need not be tubular or channel-shaped, it is convenient to extend the tension member 35 through spacers of this type. If desired, the tension member 35 can extend through eyelets of members (not shown) attached to the exterior of solid spacers. The spacers 31 and 33 preferably have pulleys 34 attached thereto to facilitate movement of the tension member 35 relative to the spacers.

[0031] As seen in FIG. 2B, it may be desirable to include among the scissor assemblies one or more sliding scissor assemblies having first and second struts that are both pivotably connected and slidable relative to one another. In FIG. 2B, the scissor assembly 23s is shown with longitudinal slots 29s (FIGS. 8C, 9C, 10C; in phantom in FIG. 2B) in both the first and second struts 25 and 27. The slots 29s permit the first and second struts 25 and 27 to slide relative to one another in addition to pivoting. Although FIG. 2B shows both struts 25 and 27 with slots 29s, it will be appreciated that a slot may be provided in just one of the struts, as well. Providing slots 29s in at least some of the struts of the scissor assemblies has been found to facilitate raising the structure 21 from a collapsed position and provides an additional degree of flexibility to an erected structure, which can be useful in adverse conditions such as high winds. It has been found to be particularly beneficial to provide slots 29s in struts closer to the lateral ends of the structure, although slots may be provided in struts near the top of the erected structure, if desired. If desired, pivot pins can be omitted entirely in some scissor assemblies.

[0032] As seen in FIG. 3A, spacers 131 may instead include separable first and second halves 131a and 131b. Ends of the first and second halves 131a and 131b are caused to abut when the slack in the tension member 35 is taken up. As seen in FIGS. 3A and 3B, the abutting ends 131a" and 131b' of the first and second halves of the spacers can be

capped by caps 47 that have holes 49 formed therein that are preferably substantially the same size as the tension member 35. When slack in the tension member 35 is taken up, the holes 49 and their associated spacer halves 131a and 131b will align as seen in FIG. 3A.

[0033] As seen in FIGS. 3A, the spacer halves 131a and 131b are preferably provided with pulleys 134 attached to the spacers at first and second ends 131a' and 131b" of the spacer halves. The pulleys 134 can be disposed in cut-out regions 135 of the spacer halves as shown in FIGS 3A, 3C, and 3D, but may also be attached to the spacers in any number of suitable ways.

[0034] As seen in FIGS. 3A and 3C, the spacer halves 131a and 131b can also be attached to hubs 137 to which the ends of the first and second struts of the scissor assemblies 23 can be pivotably attached. The hubs 137 may be in the form of hubs such as are disclosed in U.S. Patent No. 4,280,521 or other ones of the patents that are incorporated by reference. The hubs 137 shown in FIGS. 3A and 3C, however, are flanges with openings 139 to receive pivot pins that extend through openings at the ends of the first and second struts. The flanges are riveted to the spacer halves 131.

[0035] As seen in FIG. 2B, the tension member 35 is ordinarily fixed at one end 35' to an end of a scissor assembly, in this case the scissor assembly 23c. A reel 51 is disposed at an opposite end 35" of the tension member 35. The reel 51 may be attached directly to a scissor assembly or disposed remote from the scissor assemblies. The reel 51 is adapted to take up and release slack in the tension member 35. The reel 51 may be manually operated or driven by a motor 53. Where the structure includes multiple banks of scissor assemblies, it may be convenient to arrange reels on opposite ends of

alternating ones of the scissor assemblies as seen in FIGS. 4B, 5B, and 6B. Additionally, if desired, multiple reels can be driven by a common drive member which can be manually operated or driven by a single motor.

[0036] As seen in FIG. 2B, the tension member 35 extends from a first end of at least one of the first and second struts 25 and 27 to a second end of the one of the first and second struts. In FIG. 2B, the tension member 35 extends from a first end 27' of the second strut 27 proximate where the reel 51 is mounted, through or along the first spacer 31 to the first end 25' of the first strut 25, through or along the first strut 25 to the second end 25" of the first strut, and through or along the second spacer 33 to the second end 27" of the second strut. At points between the reel 51 and the point where the first end 35' of the tension member 35 is disposed, the tension member ordinarily extends over pulleys 57 attached to the ends of the struts 25 and 27 of each scissor assembly 23 in the structure and/or to the spacers 31 and 33 or 131. Additional guides for the tension member 35 such as eyelet members 55 secured to the struts 25 and 27 can also be provided.

[0037] FIGS. 4A-4C, 5A-5C, and 6A-6C show structures 21a, 21b, and 21c, respectively, having various configurations of curved and straight scissors arranged in banks to form different shapes. The shapes of the structures 21a, 21b, and 21c are substantially the same size along their length, i.e., the structures define arches of substantially constant size.

[0038] As seen in FIGS. 7A and 7B, structures 21d with different configurations may also be provided. In the structures 21d, tension members 35a, 35b, 35c, 35d, 35e, 35f are each connected to a reel 51 and extend along two non-parallel, consecutive banks 37a' and 37b", 37b' and 37c", 37c' and 37d", 37d' and 37e", 37e' and 37f", and 37f' and

37a", respectively. Two parallel, consecutive banks 37a' and 37a", . . . , 37f' and 37f" define one of six radially extending leg structures 59. The legs 59 can be connected to one another by other tension members 61 such as cables or structure covers or struts.

[0039] In all of the structures shown in FIGS. 4A-4C, 5A-5C, 6A-6C, and 7A-7B, lateral scissor assemblies or tension members can be selectively omitted between otherwise connected banks 37 to facilitate providing entrances 63 for the structures. Tension members 65 such as cables preferably extend diagonally across modules defined by scissor assembly pairs on adjacent banks and adjacent lateral scissor assembly pairs to provide additional strength to the structures. Masts 67 are preferably provided along the sides of the structures 21, 21a, 21b, 21c, and 21d, and at the top of the structure 21d to assist in forming the structures, such as by providing higher roof peaks or vertical walls. The masts 67 can be supported by tension members or attached to struts.

[0040] A method of deploying a mechanically deployable structure 21 is described with reference to FIGS. 8A-11F. The structure 21 is unfolded from the folded condition shown in FIG. 8A-8D and 11A to a collapsed condition. The structure 21 may be unfolded only along its length dimension as shown in FIG. 11B by unfolding and extending the telescoping struts 41 and 43 of the lateral scissors 39 without also unfolding the struts 25 and 27 of the scissors 23. An edge of the structure 21 can be secured to a base B such as the ground or a portable, prefabricated base, and the structure can then be extended to its full width as seen in FIG. 11C where the opposite edge of the structure can be secured to the base. The connection to the ground or base may be by any suitable means, such as a stake 69 (FIG. 1) or by protrusions (not shown) provided in a base B (FIGS. 11B-11F) that mate with holes in flanges extending from the ends of the

scissor assemblies 23_1 and 23_2 at opposite ends of the bank 37 of scissor assemblies. If desired, of course, the structure 21 may be expanded from the condition in FIG. 11A to the condition in FIG. 11C without expanding the structure to the condition shown in FIG. 11B, i.e., the structure can be expanded along its length and along its width substantially simultaneously.

[0041] Because the structure 21 need not extend beyond its erected base dimensions during erection, any covers desired on the structure can remain on the structure 21 at all times, even during folding, or may be removed prior to folding. As seen in FIG. 11D, once the structure 21 is fixed to a base B yet not fully erected, so that the still collapsed structure is fit atop the footprint of the final shape of the structure, if not already on the structure, an outer cover C can be attached. The structure 21 can then be erected to its final shape as seen in FIG. 11E and, if not already attached to the structure, an inner cover C can be attached as seen in FIG. 11F.

[0042] FIGS. 8A and 8B show a structure 21 in a folded condition. FIG. 8C shows a folded scissor assembly 23 with an enlarged view of the location of a pivot pin 29 in the slots 29s in the struts 25 and 27. The scissor assembly 23 with slots 29s is ordinarily a curved scissor assembly. FIG. 8D shows a folded lateral scissor assembly 39 in which the telescoping portions 41a and 41b and 43a and 43b of the struts 41 and 43 are telescoped in a substantially closed condition.

[0043] FIGS. 9A and 9B show the structure 21 in a partially expanded, but still collapsed condition. Comparing FIGS. 8C and 9C shows the relative movement of the pivot pin 29 relative to the slots 29s that may occur during erection of the structure 21. FIG. 9D shows the telescoping portions 41a and 41b and 43a and 43b of the struts 41 and 43

telescoped outwardly to a point where an attached cover C is placed in tension, after which it is no longer possible to extend the telescoping portions. Preferably, the telescoping portions are sized such that the cover C can be placed in tension while the scissor assembly 23 remains in the folded condition shown in FIG. 8C so that the structure can be extended along its length dimension and connected to a base B (FIGS. 11B-11F) before unfolding the scissor assemblies 23.

[0044] FIGS. 10A and 10B show the structure 21 in an expanded condition. In this condition, the spacer halves 131a and 131b are disposed adjacent to one another. In the scissor assembly 23, the pivot pin 29 will reach a final position relative to the slots 29s in the struts 25 and 27, although flexing of the scissor assembly may result in relative movement of the pin and the slots. The telescoping portions 41a and 41b and 43a and 43b of the struts 41 and 43 telescope back inwardly to a final position as seen in FIG. 10D.

[0045] With reference to FIG. 1, when the structure 21 is in a collapsed condition, slack in the tension member 35 is taken up by operating the reel 51. The tension member 35 is connected to the first and second struts 25 and 27 of the connected scissor assemblies in such a manner that taking up slack draws the first ends 25' and 27' of the first and second struts toward one another. The second ends 25" and 27" of the first and second struts will also ordinarily be drawn toward one another at the same time. Slack in the tension member 35 is taken up until the first ends 25' and 27' of the first and second struts 25 and 27 are separated by a distance defined by the first spacer 31. Taking up slack in the tension member 35 also draws the second ends 25" and 27" of the first and second struts 25 and 27 together until they are separated by a distance defined by the second spacer 33.

[0046] When the structure 21 includes two or more banks 37 of scissor assemblies 23, slack in tension members 35 corresponding to each bank of scissor assemblies is taken up. The slack in the multiple tension members 35 can be taken up substantially simultaneously, such as by driving all of the reels by a common drive. Of course, if desired, slack in the tension members 35 can be taken up at different times.

[0047] While this invention has been illustrated and described in accordance with a preferred embodiment, it is recognized that variations and changes may be made therein without departing from the invention as set forth in the claims.